BASIC ELECTRONICS ENGINEERING

(RBL1B002)

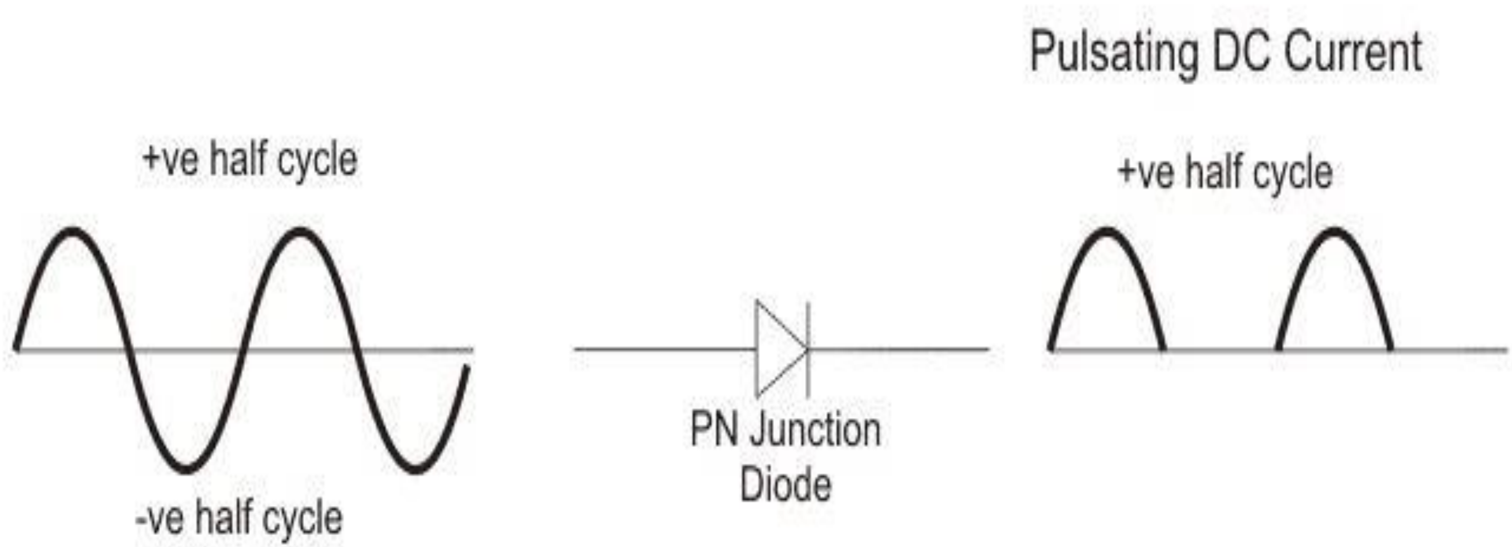
<u>MODULE-1</u>

Rectifier

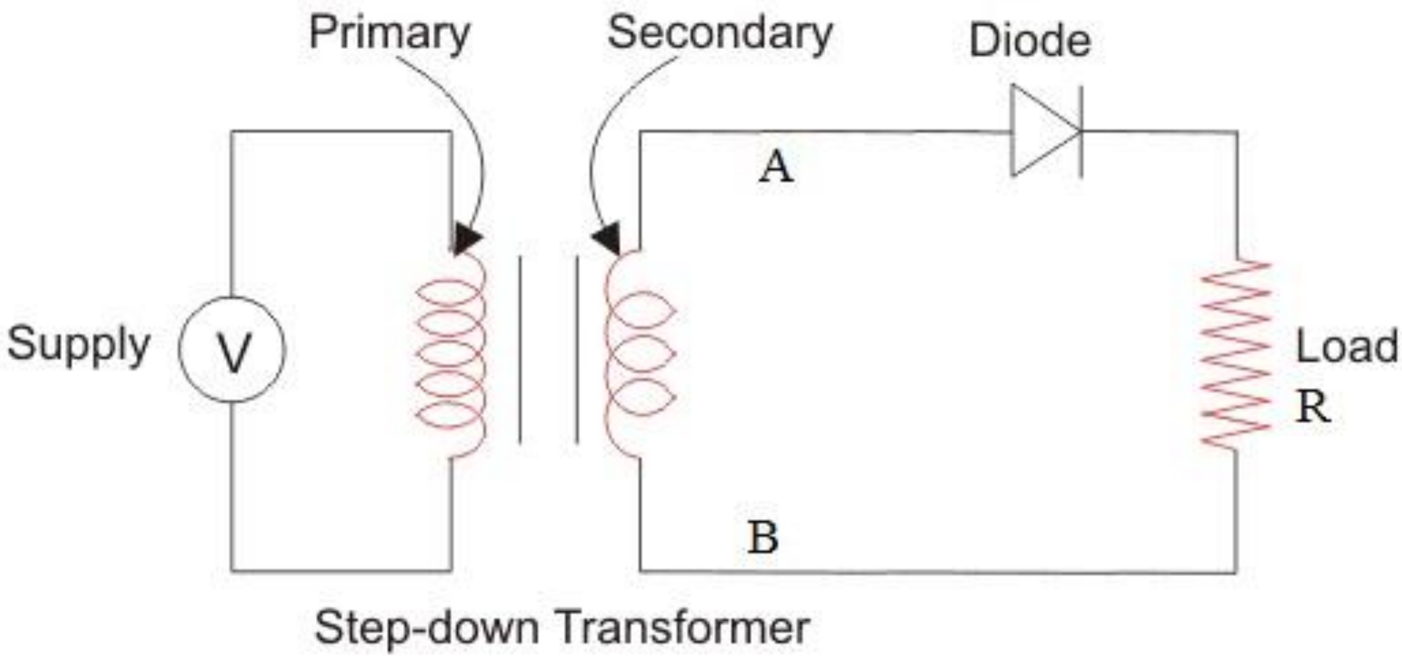
- A **rectifier** is an electrical device that converts alternating current (AC) to direct current (DC).
- It is of two types.
  - Half-Wave Rectifier
  - Full-Wave Rectifier
    - Center Tap Rectifier
    - Bridge Rectifier

Half-Wave Rectifier

Principle of Operation:



Circuit:



Primary
Secondary
Diode
A
Supply
V
Load
R
B
Step-down Transformer

Operation:

- During positive half cycle of the supply, the end A of the secondary winding is at higher potential than the end B. This makes the diode forward biased.
- So the diode starts to conduct and output can be observed across the resistance $R_{L.}$ The output will be same as the positive half of the input.
- During negative half cycle of the supply, the end A of the secondary winding is at lower potential than the end B. This makes the diode reverse biased.
- So the diode will not conduct and there will be no output for this.

Circuit Analysis:

Let us assume that the input voltage to the half wave rectifier is defined as $V_S = V_{Smax}Sin(\omega t)$ and the current observed for this voltage is defined as $i = I_{max}Sin(\omega t)$.

1. **PIV (Peak Inverse Voltage):**

- It is the maximum voltage that the diode has to withstand during reverse bias condition.
- For half wave rectifier during –ve half cycle, diode becomes reverse bias and the entire voltage appears across the diode. So the PIV of the half wave rectifier is

$$\text{PIV} = V_{smax}$$

2. Peak Current:

It is given by $I_{max} = \frac{V_{smax}}{R_f + R}$

where R_f = forward resistance of the diode.

3. Output Current:

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} id(\omega t)$$

$$=> I_{dc} = \frac{1}{2\pi}\int_0^{\pi} [I_{max}Sin(\omega t)]d(\omega t)$$

$$=> I_{dc} = \frac{1}{2\pi} I_{max} \int_0^{\pi} [Sin(\omega t)]d(\omega t) = \frac{1}{\pi} I_{max}$$

4. Output Voltage:

$$V_{dc} = I_{dc}R = \frac{I_{max}}{\pi}R$$

5. RMS value of current:

The current flowing through the diode is given by

$$I_{rms}{}^{2} = \frac{1}{2\pi}\int_{0}^{2\pi} i^{2} d(\omega t)$$

$$=> I_{rms}{}^{2} = \frac{1}{2\pi}\int_{0}^{\pi} (I_{max}Sin\omega t)^{2} d(\omega t)$$

$$=> I_{rms} = \frac{I_{max}}{2}$$

6. RMS value of Voltage:

$$V_{rms} = I_{rms} \cdot R$$

7. Ripple factor:

The ripple voltage/current present in the output of the rectifier is measured in terms of ripple factor. It is given by

$$\gamma = \frac{I_{ac}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$\Rightarrow \gamma = \sqrt{\left[\frac{I_{rms}}{I_{dc}}\right]^2 - 1} = \sqrt{K_f^{\ 2} - 1}$$

K_f = form factor

$$K_f = \frac{I_{rms}}{I_{dc}} = \frac{I_{\max}/2}{I_{\max}/\pi} = \frac{\pi}{2} \approx 1.57$$

So ripple factor is given by,

$$\gamma = \sqrt{K_f^{\,2} - 1} = \sqrt{(1.57)^2 - 1} = 1.21$$

8. Rectification Efficiency:

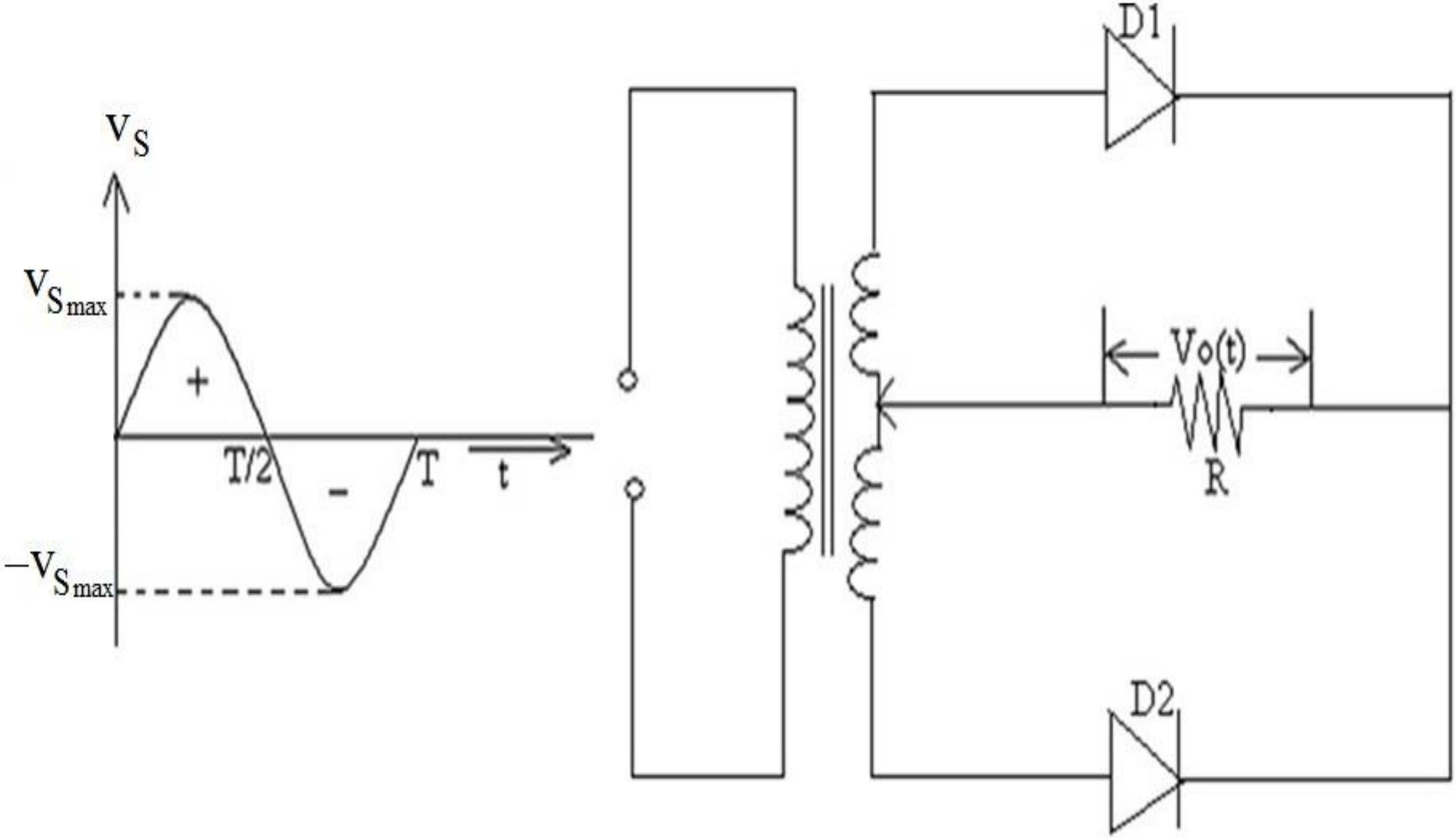
$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I^2{}_{dc} R}{I^2 rms(R + R_f)}$$

$$= 0.406 \ or \ 40.6\%$$

Full-Wave Rectifier

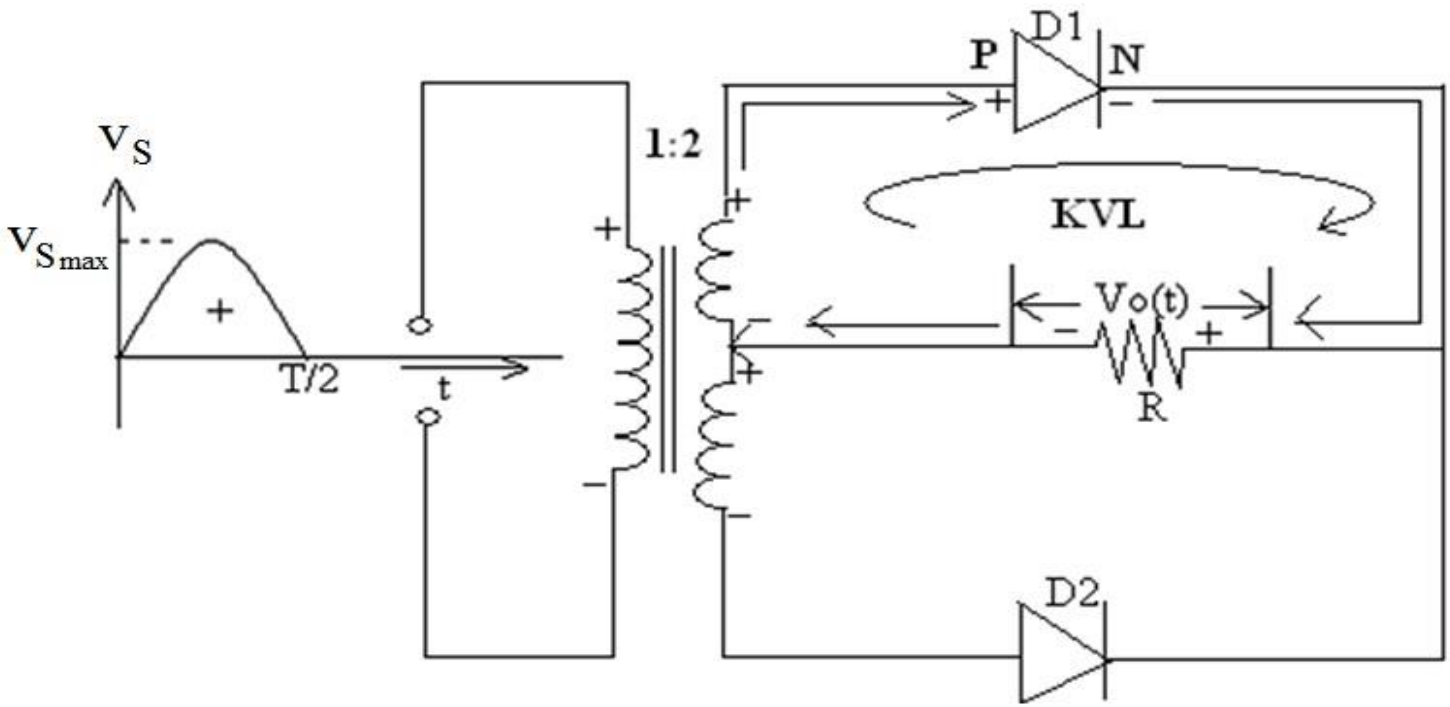
- In half wave rectifier, only one half of the input is utilized to produce an output. Hence the efficiency is very low.
- But the full wave rectifier uses both the half cycles of the input to produce output.
- The full wave rectifier is of two types.
  - Center tap Rectifier
  - Bridge rectifier

Center Tap Rectifier



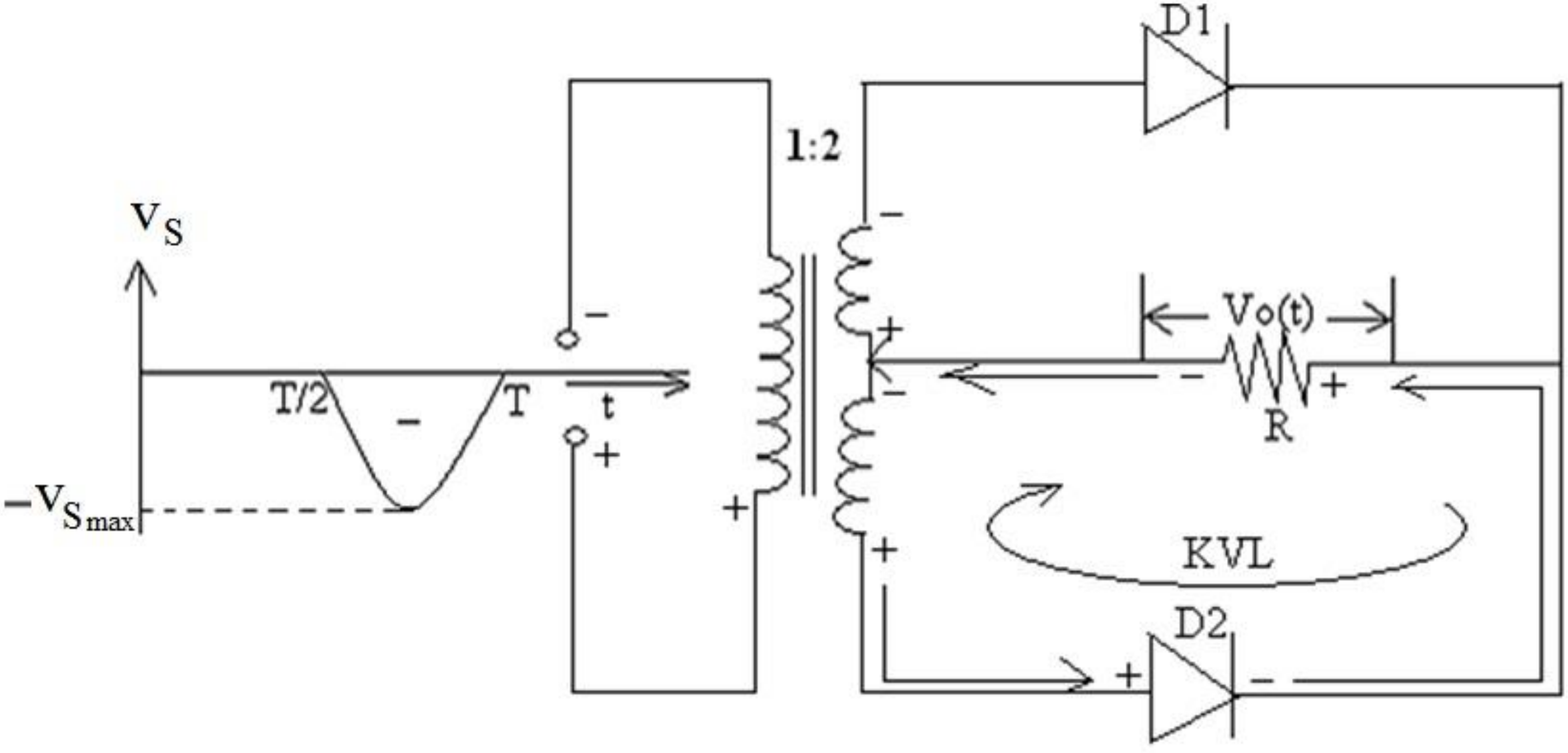
Operation:

- During positive half cycle diode D_1 is forward biased & diode D_2 is reverse biased.
- Hence current flows through diode D_1, through resistor R and upper half of the secondary winding.

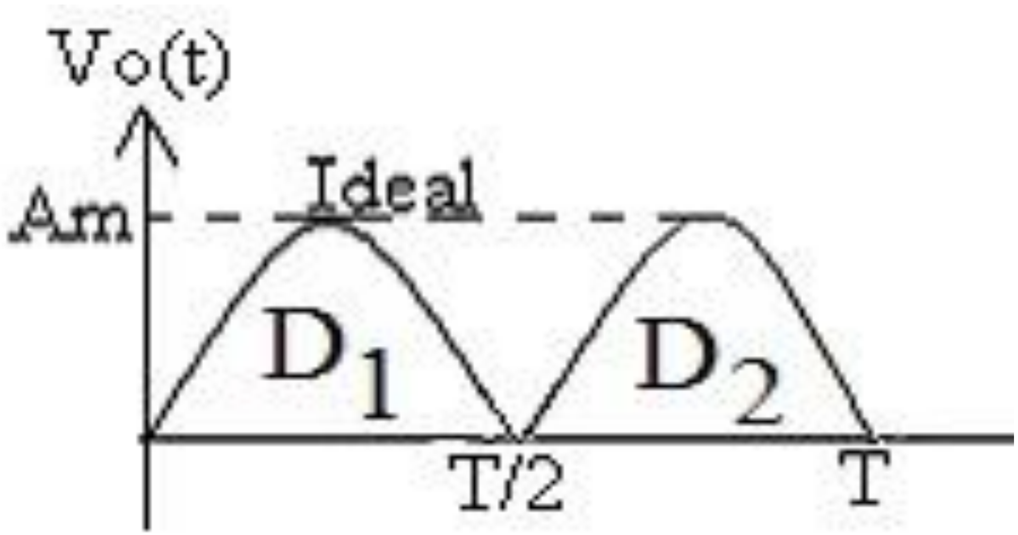


Operation:

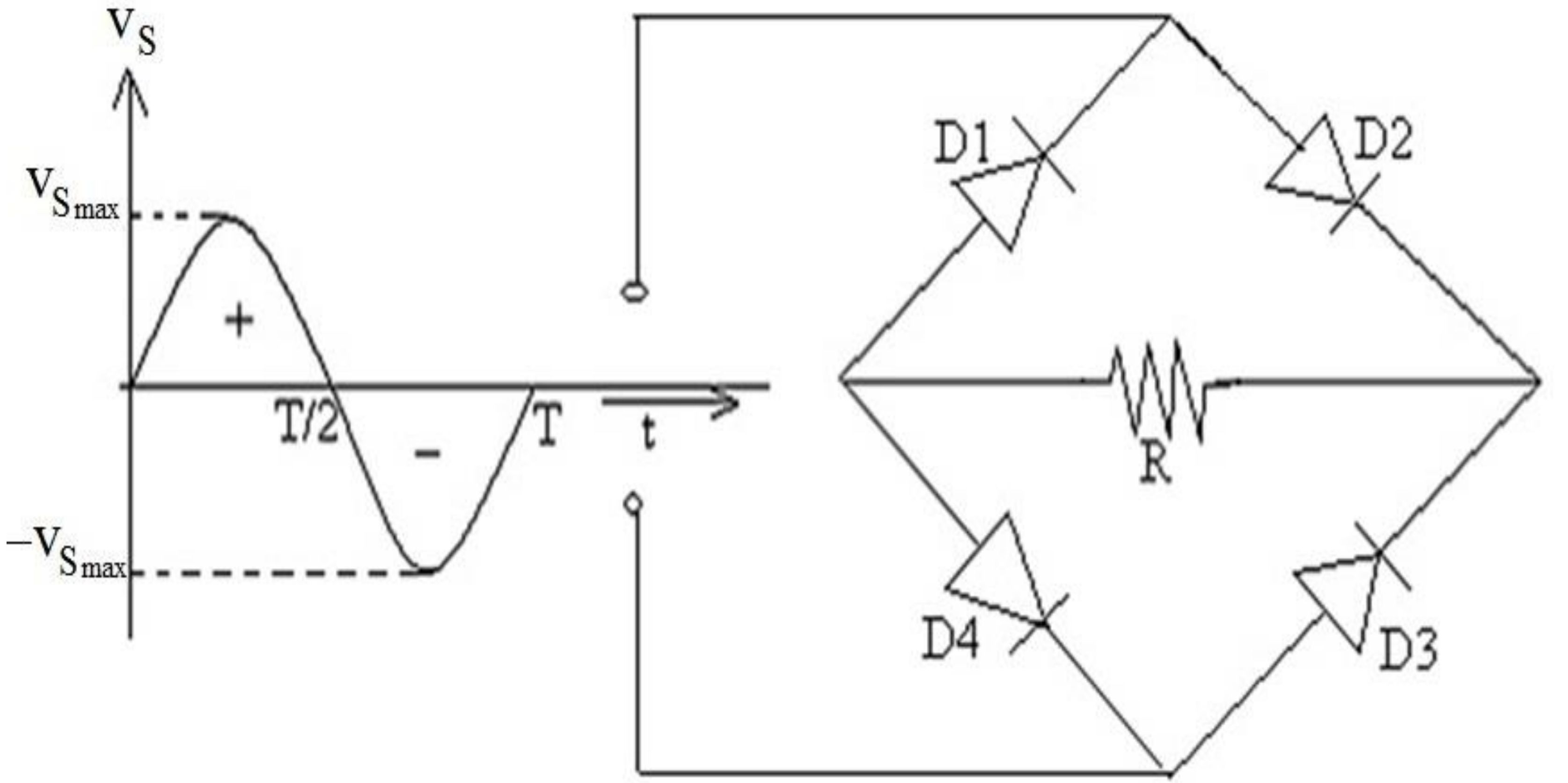
- During negative half cycle diode D_2 is forward biased & diode D_1 is reverse biased.
- Hence current flows through diode D_2, through resistor R and upper half of the secondary winding.



- The current through R for both the half cycles are in the same direction. Hence DC is obtained across R.

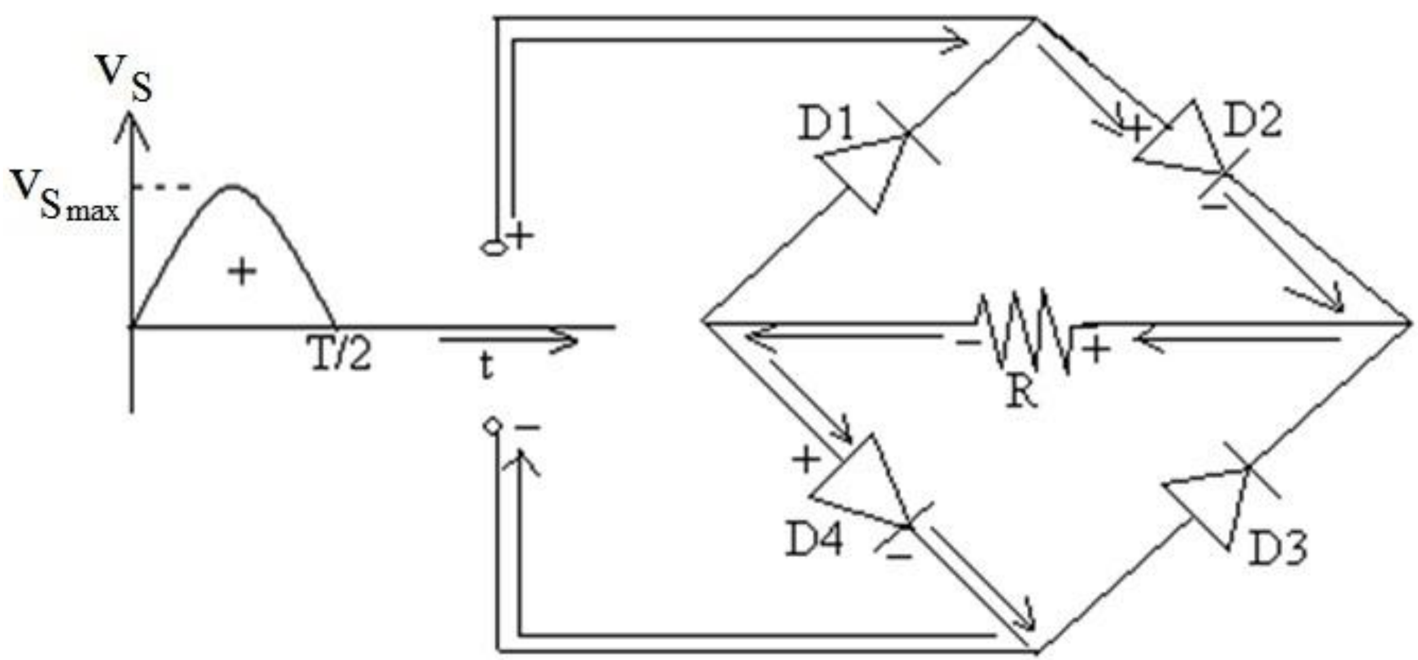


Bridge Rectifier



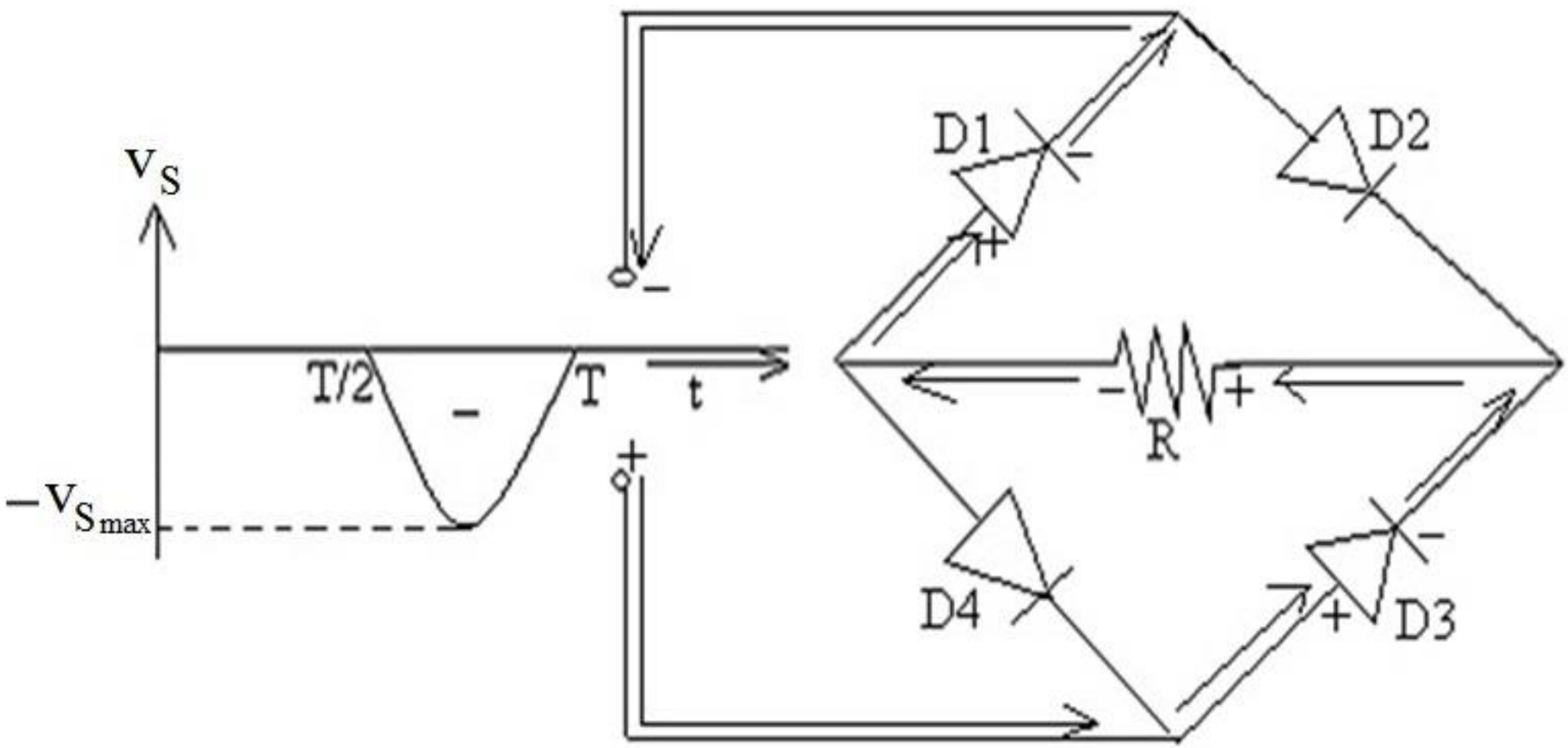
Operation:

- In the bridge circuit 4 diodes are connected to form the bridge.
- During positive half cycle the diodes D_2 and D_4 are forward biased. Diodes D_1 and D_3 are reverse biased.
- Hence current flows through diode D_2 through resistor R & diode D_4.



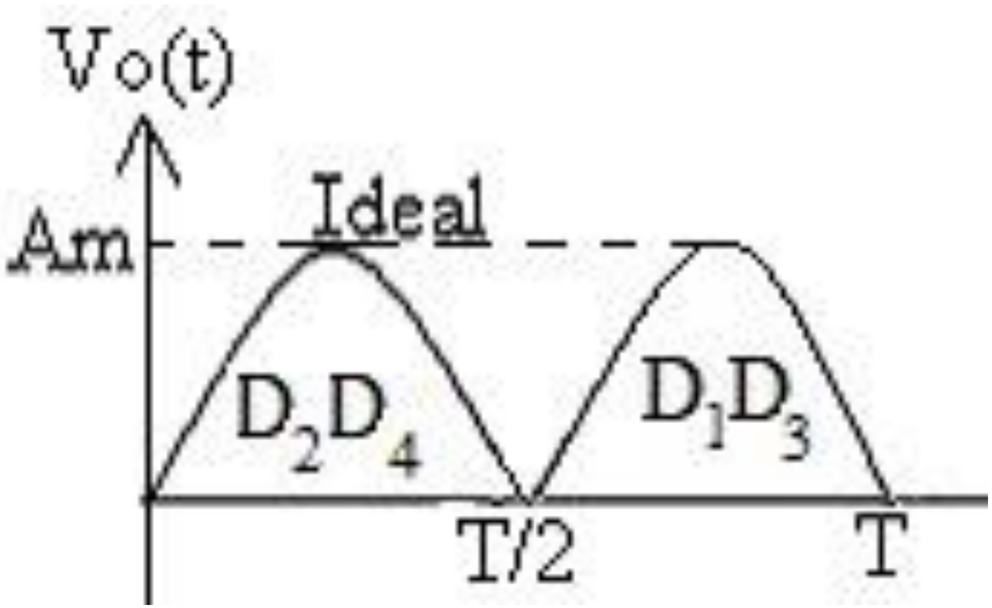
Operation:

- During negative half cycle the diodes D_1 and D_3 are forward biased. Diodes D_2 and D_4 are reverse biased.
- Hence current flows through diode D_3 through resistor R & diode D_1.



Operation:

- The output of the bridge rectifier is shown below



Circuit Analysis:

Let us assume that the input voltage to the half wave rectifier is defined as $V_S = V_{Smax}Sin(\omega t)$ and the current observed for this voltage is defined as $i = I_{max}Sin(\omega t)$.

1. PIV (Peak Inverse Voltage):

- PIV *(FOR CENTER TAP)* = $2V_{smax}$
- PIV *(FOR BRIDGE)* = V_{smax}

2. Peak Current:

$$For\ Center\ tap : I_{max} = \frac{V_{smax}}{R_f + R}$$

$$For\ Bridge : I_{max} = \frac{V_{smax}}{2R_f + R}$$

where R_f = forward resistance of the diode.

3. Output Current:

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i d(\omega t)$$

$$=> I_{dc} = \frac{2I_{max}}{\pi}$$

4. Output Voltage:

$$V_{dc} = I_{dc}R = \frac{2I_{max}}{\pi}R$$

5. RMS value of current:

The current flowing through the diode is given by

$$I_{rms}{}^2 = \frac{1}{2\pi}\int_0^{2\pi} i^2 d(\omega t)$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} i^2 d(\omega t) + \int_{\pi}^{2\pi} i^2 d(\omega t)\right]$$

$$=> I_{rms}{}^2 = \frac{1}{2\pi} 2 \cdot \int_0^{\pi} (I_{max} Sin\omega t)^2 d(\omega t)$$

$$=> I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

6. RMS value of Voltage:

$$V_{rms} = I_{rms} \cdot R$$

7. Ripple factor:

The ripple voltage/current present in the output of the rectifier is measured in terms of ripple factor. It is given by

$$\gamma = \frac{I_{ac}}{I_{dc}} = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

$$\Rightarrow \gamma = \sqrt{\left[\frac{I_{rms}}{I_{dc}}\right]^2 - 1} = \sqrt{K_f^{\ 2} - 1}$$

K_f = form factor

$$K_f = \frac{I_{rms}}{I_{dc}} = \frac{I_{\max}/2}{I_{\max}/\pi} = \frac{\pi}{2} \approx 1.57$$

So ripple factor is given by,

$$\gamma = \sqrt{K_f{}^2 - 1} = \sqrt{(1.57)^2 - 1} = 1.21$$

8. Rectification Efficiency:

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{I^2{}_{dc} R}{I^2 rms(R + R_f)}$$

$$= \frac{\left({}^{2I_{max}}/{}_{\pi}\right)^2}{\left({}^{I_{max}}/{}_{\sqrt{2}}\right)^2}$$

$$= \frac{\left(2\sqrt{2}\right)^2}{\pi^2}$$

$$= 0.812 \text{ or } 81.2\%$$

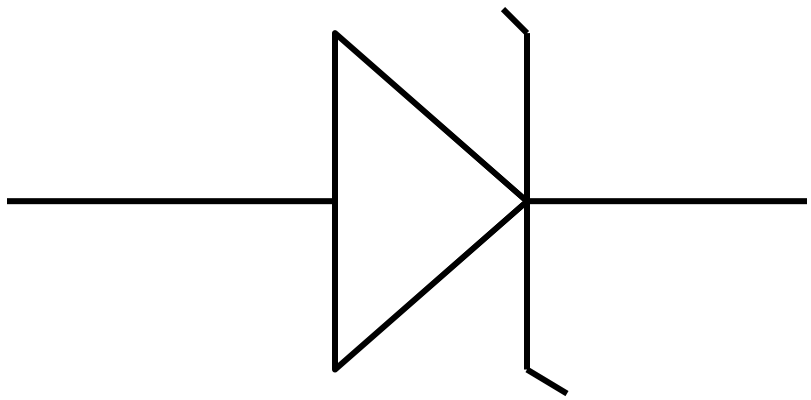
Special Diode

3 types of special diodes are there.

- Zener Diode
- Avalanche Diode
- LED (Light Emitting Diode)

Zener Diode

Symbol:



- When the reverse bias voltage of a diode is increased sufficiently, junction breakdown occurs. A sharp increase in reverse current can be observed.
- The voltage at which breakdown occurs is known as breakdown voltage or zener voltage.

Zener Diode

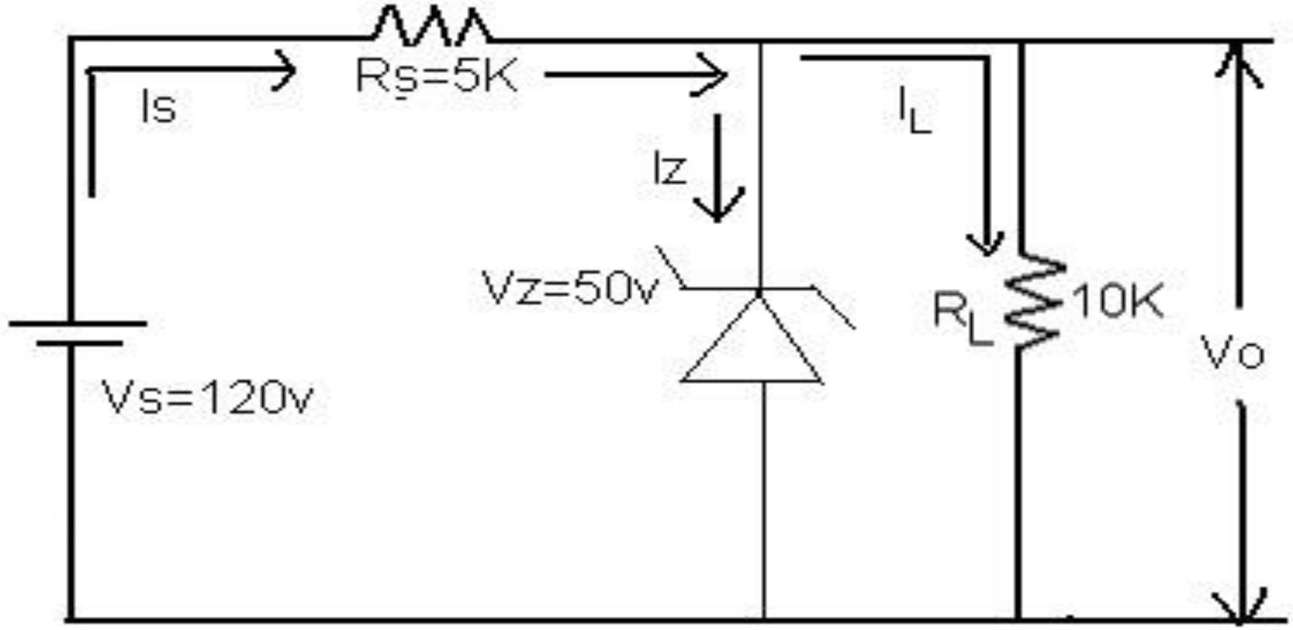
- This breakdown voltage or zener voltage depends upon the doping concentration.
- If the junction is heavily doped, the width of the depletion region will be thin and the breakdown will occur at a lower reverse voltage.
- When the junction is lightly doped, the width of the depletion region will be more and the breakdown will occur at a higher reverse voltage.
- Hence a properly doped diode having a higher breakdown voltage is called *zener diode*.

Zener Diode

- The zener diode is a special type of diode designed to operate in breakdown region.
- Zener diode allows current in forward direction like normal diode. It also allows current in reverse direction if the applied reverse voltage is greater that the zener voltage.
- Zener diode is always connected in reverse direction.
- Application of Zener Diode
  - voltage regulator
  - Meter protection
  - Wave Shaper

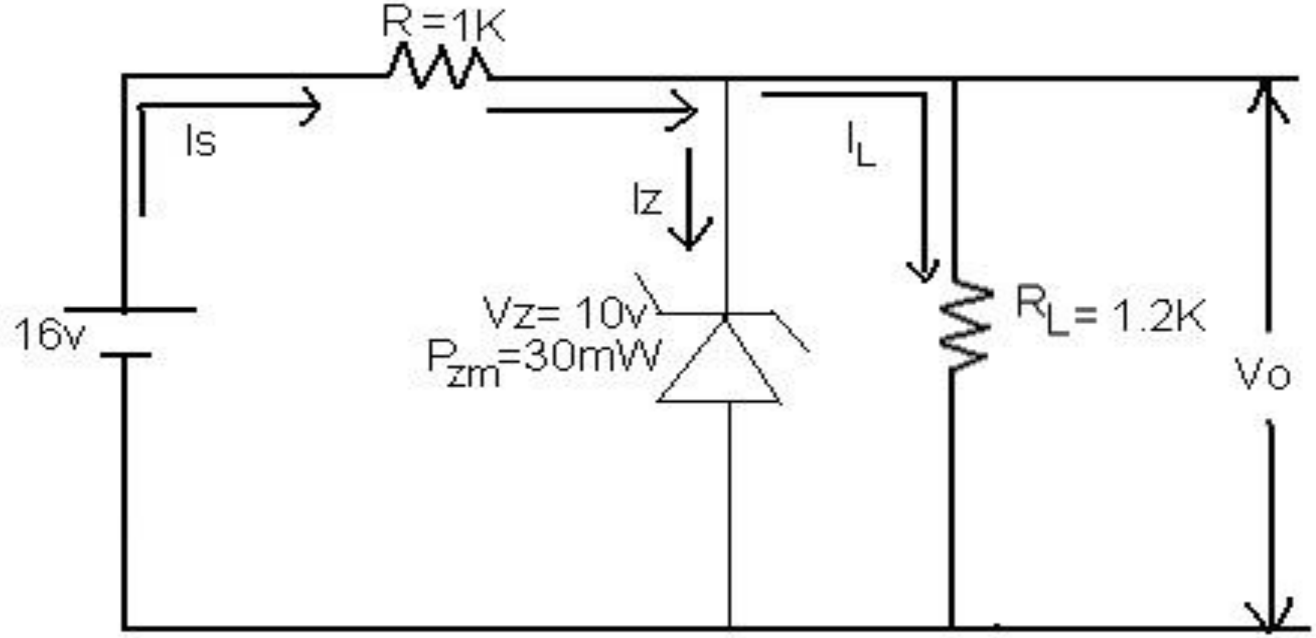
PRACTICE

Example:



- For the circuit shown in fig. find
  - The output voltage
  - The voltage drop across Rs
  - The current through zener

Example:



- Determine V_L, V_R, I_Z, and P_Z for the zener diode shown in the figure.

Avalanche Diode

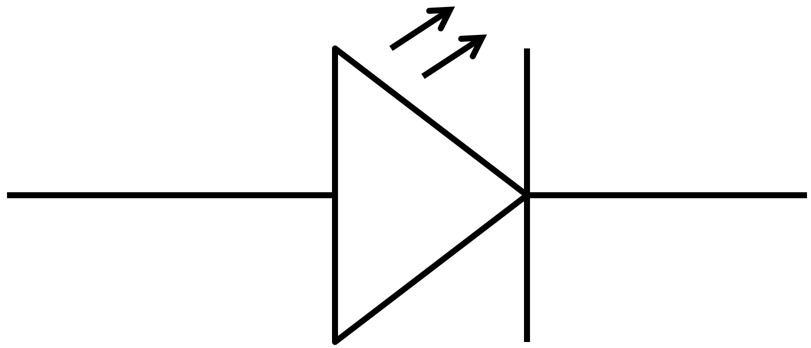
- An avalanche diode is a type of semiconductor diode which is designed to experience avalanche breakdown at a specified reverse bias voltage.
- The PN junction of an avalanche diode is designed to remain undamaged by the avalanche breakdown.
- The construction of the avalanche diode is similar to the Zener diode but they are optimized for avalanche breakdown conditions.
- In the Zener diode, the depletion region is thin and because of the thin depletion layer of the Zener diode, the reverse breakdown occurs at a lower voltage.

Avalanche Diode

- But in the case of the avalanche diodes, the width of the depletion region is more due to a lightly doped junction. Hence, the reverse breakdown occurs at high voltage.
- The symbol of the avalanche diode is the same as the symbol of the Zener diode.
- Like zener diode, avalanche diode also allows the current under both the conditions (Forward bias & Reverse bias).

LED (Light Emitting Diode)

Symbol:



- The LED is a special type of diode which produces light when bias voltage is applied.
- In normal PN junction diode recombination process starts during forward bias condition.
- Due to recombination the energy of the free electrons change their state. Some of their energy is converted to heat energy and rest is converted to photons.

LED (Light Emitting Diode)

- In case of normal diode (Si or Ge) most of the energy is converted to heat energy and the emitted light is not significant.
- In some materials such as GaP (Gallium Phosphide) and GaAsP (Gallium Arsenide Phosphide) the number of photons emitted is sufficient to produce visible light.
- The process of producing light by applying an electrical source is called as *electroluminescence*.